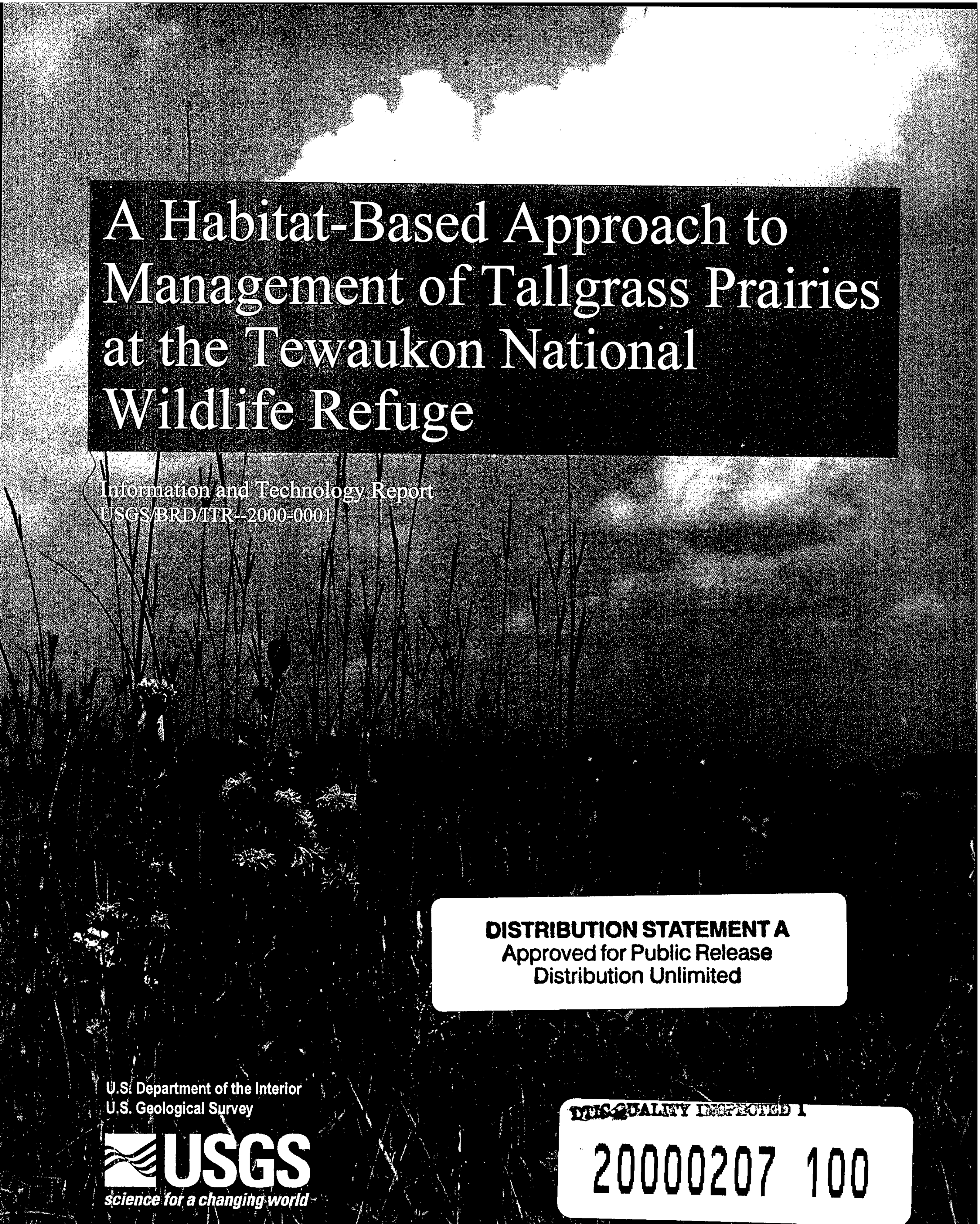

A Habitat-Based Approach to Management of Tallgrass Prairies at the Tewaukon National Wildlife Refuge

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November 1999

By
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U.S. Department of the Interior
U.S. Geological Survey

Cover photograph courtesy of Darla Lenz, North Dakota Parks and Recreation Department, Bismarck.

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Introduction

National Wildlife Refuge System lands are required, through the National Wildlife Refuge System Improvement Act of 1997, to be managed in accord with approved Comprehensive Conservation Plans (CCPs). Plans for each National Wildlife Refuge (NWR) must be completed within 15 years of the date of the Act. These Plans will provide detailed guidance on various aspects of NWR management, and a major segment of each CCP will be devoted to providing direction for habitat management activities on NWR lands.

The Improvement Act requires that each refuge be managed to contribute to the mission of the overall refuge system and fulfill the individual refuge purposes. The refuge system mission calls for the conservation, management, and restoration of fish, wildlife, and plant resources, and their habitats, and the maintenance of biological integrity and diversity. The purposes of each NWR are often more specific.

Individual refuges are now moving forward in the development of CCPs and identification of specific habitat objectives. This process is underway at Tewaukon NWR, located in the southeastern corner of North Dakota. An initial step in the CCP process is to identify and learn about the specific resources of concern on each refuge.

Uplands at the latitude of Tewaukon NWR are on the western edge of the tallgrass prairie (Risser et al. 1981); and tallgrass prairie east of the Missouri River and on mesic sites across its range is listed as a critically endangered ecosystem with a >98% decline in total area (Noss et al. 1995). The U.S. Fish and Wildlife Service (FWS) has begun an effort to conserve tallgrass prairies in western Minnesota and northwestern Iowa (U.S. Fish and Wildlife Service 1998). Maintenance or restoration of native biodiversity within tallgrass prairie ecosystems is a high priority in these regions and at the Tewaukon NWR.

Specific, measurable habitat objectives should be formulated using well-documented, scientifically sound sources. The purpose of this report is to provide such information to guide habitat management efforts to maintain or restore native biodiversity within the tallgrass prairie at Tewaukon NWR. Much of the information likely applies to tallgrass prairies in eastern North and South Dakota and western Minnesota to the extent that the key species are present. We follow the general process recommended in a recently published report on selecting habitat management strategies on NWRs (Schroeder et al. 1998), presenting information on: (1) an overview of tallgrass prairie ecosystems; (2) identification of resources of concern; (3) habitat and life history information for

the resources of concern; (4) establishing habitat objectives; (5) potential habitat management strategies; and (6) monitoring, evaluation, and adaptive management.

The term biodiversity has been used in a number of ways, and is subject to much interpretation (DeLong 1996). We agree with DeLong that any specific definition of biodiversity should clearly describe the meaning of the term, and not be limited by what can or will be measured and managed. We define biodiversity as:

> "An attribute of an area referring to the variety within and among living organisms, biotic communities, and biotic processes. Biodiversity can be measured in terms of genetic diversity and the identity and number of different types of species, biotic communities, and biotic processes, and the amount (e.g., abundance, biomass, cover, rate) and structure of each. It can be observed and measured at any spatial scale ranging from microsites and habitat patches to the entire biosphere" [adapted from (DeLong 1996)].

We include the modifier "native" with biodiversity to indicate that we are concerned with maintaining or restoring the biota and processes that are native to tallgrass prairies.

Overview of Tallgrass Prairie Ecosystems

Tallgrass prairie was the dominant vegetation type across the eastern portion of the Great Plains during presettlement times (Steinauer and Collins 1996). Most of the original estimated 60 million ha was plowed for agricultural production within a short time after European settlement. Samson and Knopf (1994) estimate there has been a 99.9% decline in area of tallgrass prairie in North Dakota. Climate, topography, fire, and grazing are the primary factors influencing the development and maintenance of prairie ecosystems (Wells 1970). The interaction of these factors creates a mosaic of habitat conditions along a vegetational continuum of height, density, and amount of woody growth (Ryan 1986).

In tallgrass prairie habitats, grassland birds are of particular concern because they have exhibited steeper, more consistent declines during the past 25 years than any other group of North American birds (Knopf 1995). Conservation of native prairie birds and other wildlife requires a mosaic of habitat conditions within large grasslands (Skinner et al. 1984; Renken and Dinsmore 1987; Volkert 1992; Howe 1994; Madden 1996). Howe (1994) recommends management for tallgrass assemblages that are diverse, different from each other, and dynamic. A variety of grassland plant species abundance distributions should be encouraged to maximize prairie biodiversity. Skinner et al. (1984) recommend managing for a wide range of cover heights during all seasons to provide the best wildlife habitat in Missouri grasslands. Madden (1996) emphasizes the need to manage for all stages of prairie succession to provide for maximum grassland bird diversity over decades of management. The habitat affinities of grassland bird species are diverse, and species respond to similar conditions in different ways (Wiens 1969; Herkert 1994a).

Species richness of grassland birds is positively associated with size of the grassland area, and large prairies are important for conserving prairie bird populations (Herkert 1994b). Area is an important and consistent feature of the ecology of grassland bird species, and adequate area is a critical habitat requirement for these species (Vickery et al. 1994). Herkert et al. (1993) recommend managing for grasslands at least 50 ha and preferably >100 ha in area to benefit bird species that are most sensitive to grassland fragmentation. Burger et al. (1994) found that artificial nests in prairies <15 ha had higher predation rates (37%, $P < 0.001$) than in larger prairies (13.9%). Artificial nests <60 m from woody cover had more predation (28.7%, $P < 0.001$) than those >60 m (7.9%). Large grassland areas also provide habitat for many other organisms, including unique grassland plants (Vickery et al. 1994). Throughout most of the former range of tallgrass prairie almost all that remains are small, scattered tallgrass fragments (Steinauer and Collins 1996). The small size of these remaining fragments, and the resultant high proportion of edge, makes them highly susceptible to invasion by aggressive exotic vegetation (Solecki 1997).

Herkert (1994b) notes that both area and vegetation structure significantly affect grassland bird populations. Large homogeneous areas may have less value than several smaller areas with distinct vegetative components (Ryan 1986). The most abundant introduced Eurasian grasses tend to be more uniform in height and density than native vegetation (Wilson and Belcher 1989). Average height of the leaf canopy of native prairie grasses varies with flowering date. In dry mesic prairies in Wisconsin, leaf canopy height for species that bloomed in May, June, July, August, and September was about 7–10, 17–20, 26–29, 28–31, and 40–43 cm, respectively [based on information from Curtis (1959) and Butler (1954) as cited by Risser et al. (1981)]. A similar progression was found in wet prairies, with maximum leaf canopy heights of 85–88 cm in September.

Identification of the Resources of Concern

Maintenance or restoration of native biodiversity within tallgrass prairies is reasonable as a broad goal. Biodiversity in its entirety, however, cannot be adequately measured in a real world situation (DeLong 1996). In addition, it is not feasible to provide all of the components of biodiversity in tallgrass prairies that were found in presettlement times (Johnson et al. 1994). Platt (1983) indicates that a tallgrass prairie 24,000 to 61,000 ha in size would be needed to reintroduce large prairie animals, such as bison and elk, and to allow for at least semi-natural movements and grazing patterns. Reintroduction of extirpated carnivores, such as the grizzly bear, gray wolf, and mountain lion (Jones et al. 1983), is even more difficult to envision.

Issues of concern in relation to biodiversity in tallgrass prairies can be summarized and may provide a focal point for developing more specific habitat objectives. Following are some of the major concerns in remaining tallgrass areas:

- small size of contiguous patches
- lack of natural processes
- increase in the amount of woody vegetation, especially trees
- loss of diversity in plant community
- invasion by exotic plants
- rare or declining species, including grassland birds and butterflies

During the formulation of objectives, it is possible to narrow the components of biodiversity to a set that can be measured and managed (DeLong 1996). One useful approach is to manage for sensitive species, because the first signs of environmental stress often show in the population levels of such species (Odum 1992).

Several butterfly species that occur in tallgrass prairies of the Dakotas and Minnesota are of management concern, including the regal fritillary (*Speyeria idalia*), Dakota skipper (*Hesperia dacotae*), powesheik skipper (*Oarisma powesheik*), and arogos skipper (*Atrytone arogos*) (Moffat and McPhillips 1993).

We used the bird checklist for Tewaukon NWR as a starting point in selecting sensitive bird species in tallgrass habitats in this region. Vickery et al. (1999) recommend managing specific grassland sites for particular subsets of birds that are best suited to the location. Johnson (1995) lists five criteria for selecting priority bird species in managing northern prairies: (1) small breeding range; (2) small total continental population; (3) decline in number or range; (4) restricted to a narrow range of habitats; and (5) major potential threat to population. Birds of management concern have been listed for the United States by the National Audubon Society (Muehter 1998) and the U.S. Fish and Wildlife Service (1995), and for North Dakota by Berkey et al. (1993). The criteria we used for selecting birds of most concern were:

- Select species that are associates of tallgrass or mixed/tallgrass prairie.
- Select species of management concern [occurs on any of these lists: Audubon Society Watchlist (Muehter 1998), nongame migratory birds of management concern list (U.S. Fish and Wildlife Service 1995), or species of special concern (Berkey et al. 1993)].
- Select species for which Tewaukon NWR is in the central part of the species' range, not on the periphery [based on Breeding Bird Survey (BBS) maps (Sauer et al. 1995) and Stewart (1975) maps].

Based on the above considerations, and discussions with refuge staff, it was determined that the following four bird species were of highest priority in tallgrass habitats on Tewaukon NWR:

- Upland sandpiper (*Bartramia longicauda*). The upland sandpiper is on the FWS (1995) list. Samson and Knopf (1996) list this species as an associate of mixed/tall and tallgrass. The species is a common breeder at Tewaukon NWR, and is most abundant in the Great Plains from North Dakota south through Kansas (Sauer et al. 1995).
- Northern harrier (*Circus cyaneus*). The northern harrier is on the FWS (1995) list. Samson and Knopf (1996) list this species as an associate of mixed/tall and tallgrass. It is listed as common on the refuge checklist and nests there. Harriers nest across much of the United States, except the southeastern states, and population declines have occurred on the Great Plains from Oklahoma to southern Canada (Sauer et al. 1995).
- Grasshopper sparrow (*Ammodramus savannarum*). This species is listed by the FWS (1995) and Berkey et al. (1993). Samson and Knopf (1996) list this species as an associate of mixed/tall and tallgrass. The species is listed as uncommon in the summer on the Tewaukon Refuge bird checklist but nests there. The grasshopper sparrow is most abundant in the Great Plains from North

Dakota south through Kansas and has experienced population declines throughout most of its range (Sauer et al. 1995).

- Bobolink (*Dolichonyx oryzivorus*). This species is on the Audubon Society's Watchlist (Muehter 1998). Bobolinks are summer residents in habitats dominated by tallgrasses. The species is common in the summer at Tewaukon Refuge and nests there. One center of bobolink abundance is in eastern North Dakota and the western edge of northern Minnesota (Sauer et al. 1995). Bobolink populations have generally declined throughout their breeding range, particularly since 1980.

This paper summarizes habitat information for the four tallgrass bird species of concern, the rare butterflies, and tallgrass flora. Based on this habitat information, we believe management for these resources will contribute substantially toward meeting the goal of maintaining native biodiversity. A specific tallgrass habitat model is presented to allow development of detailed, quantitative habitat objectives and to provide a basis for selecting management strategies and a monitoring plan. Our intent is that this approach be applied within the context of adaptive resource management.

Habitat and Life History Information for Selected Key Resources

Upland Sandpiper (Bartramia longicauda)

Range

The upland sandpiper breeding range in the contiguous United States includes an area from eastern Washington through central Colorado to north-central Texas and east to Virginia and Maryland and north to central Maine (American Ornithologist's Union 1983). The wintering grounds are in South America. Upland sandpipers are most numerous on the central Great Plains from northern Oklahoma to North Dakota (Sauer et al. 1995).

Population Status

The upland sandpiper is listed as a species of management concern by the FWS because of its dependence on vulnerable or restricted habitats (U.S. Fish and Wildlife Service 1995). Breeding Bird Survey data indicate that populations across the United States had an increasing trend of 2% per year (P <0.01) during the period 1966-1994, although the change from the period 1980–1994 (0.2% per year) was not significant (Sauer et al. 1995).

Phenology and Demographics

Upland sandpipers in North Dakota arrived most commonly on May 5, with an average nest initiation date of May 25 (Higgins and Kirsch 1975). Most birds departed by August 25. Ninety percent of nests (n = 179) in North Dakota, South Dakota, Montana, and Manitoba were initiated from May 15 to June 20 (Kantrud and Higgins 1992). The latest nest initiation date in North Dakota was noted as June 28 (Bowen and Kruse 1993). Nest densities in central North Dakota ranged from a low of 0.3 per 40.5 ha on annually tilled cropland to a high of 6.8 per 40.5 ha on grasslands during the second growing season after a prescribed burn (Kirsch and Higgins 1976). In a southcentral North Dakota grazing study, nest densities ranged from 8–22 per 100 ha (Bowen and Kruse 1993). Hatching success averaged 67% for 172 nests in grasslands, and 0% for six nests in annually tilled croplands (Kirsch and Higgins 1976). Most nest failures were from mammalian predators, thought to be primarily red foxes (*Vulpes vulpes*). Hatching success of 47 eggs from 12 nests was 91% in a Wisconsin study, where nest destruction was caused by livestock trampling (Ailes 1980).

Habitat Requirements

Upland sandpipers nested most often in native vegetation in North Dakota, South Dakota, Montana, and Manitoba, but also used stands with introduced grasses (Kantrud and Higgins 1992). Kaiser (1979) conducted nest searches in a total of 450 ha of native prairie and 515 ha of tamegrass, tamegrass and legumes, and alfalfa in southeastern South Dakota and found 33 nests in the native prairie and none in the other types. Thirty-two of the 33 nests were on native prairie with good or excellent range condition, defined as the percentage of vegetation that is climax for the site. Wilson and Belcher (1989) also found upland sandpipers to be more abundant in native mixed-grass prairie in Manitoba, and believed this may have been because the introduced Eurasian vegetation was too tall. Upland sandpiper nests in North Dakota were generally associated with grass, with 85% of 195 nests in areas with >50% grass (Kirsch and Higgins 1976).

Several studies provide information on vegetative structure of upland sandpiper habitat. Upland sandpipers generally avoid tall, dense vegetation (Bowen and Kruse 1993). In Minnesota, preferred feeding habitat was in vegetation <10 cm in height (Dorio and Grewe 1979).

Populations in feeding and loafing cover in Missouri were most dense when grass heights were 10.2–30.4 cm (Skinner 1975). A large percentage of brood rearing and late summer feeding observations in central Wisconsin were in heavily grazed areas where the vegetation was 0–10 cm tall (Ailes 1980). Upland sandpiper occurrence in Illinois grasslands was positively associated with the percent of live vegetation (Herkert 1994b).

Upland sandpipers in central North Dakota preferred to nest in cover 15.6 to 30.8 cm tall, and avoided cover >61.5 cm (Kirsch and Higgins 1976). Kaiser (1979) also reported that upland sandpipers avoid vegetation >60 cm for nesting. Twelve of 14 nest sites, at the time of discovery, were in vegetation 22.5 to 35 cm in height in a Minnesota study (Dorio and Grewe 1979). Kantrud and Higgins (1992) reported most nest sites had 100% visual obstruction <1.5 dm, effective cover height (for grasses, the top of the leaf canopy) <3 dm, and no nests were found where visual obstruction was >4 dm or effective cover height was >8.5 dm. The majority of nests in a central Wisconsin study were in vegetation 25–40 cm tall; however, when nests hatched the vegetation was as high as 70 cm (Ailes 1980).

Upland sandpipers showed little response to grazing intensity in North Dakota (Kantrud 1981). Moderate spring grazing (20–40% of current year's growth removed) in South Dakota did not restrict sandpiper nesting (Kaiser 1979). The relative abundance of upland sandpipers (in June and July) was significantly higher on burned (May 3) northern mixed prairies in South Dakota than in unburned prairies (Huber and Steuter 1984). Kirsch and Higgins (1976) recommended that native grasslands be burned every 3 years, with early May the most effective time period.

Area and Landscape Considerations

Several studies indicate that upland sandpipers are sensitive to the size of available habitat. Helzer (1996), in a study of wet meadow fragmentation in Nebraska, found upland sandpiper abundance to be positively correlated with patch area and negatively correlated with the perimeter-area ratio. Sandpipers reached 50% incidence at patch sizes of 50 ha. In Illinois prairies, sandpiper abundance was also positively associated with habitat area (Herkert et al. 1993), and the minimum area of encounter was 30 ha (Herkert 1991). In Iowa Conservation Reserve Program (CRP) fields, sandpipers were most abundant on plots that were part of larger (>50 ha) CRP tracts (Patterson and Best 1996). Vickery et al. (1994) reported that upland sandpipers in Maine reached 50% incidence in grasslands of about 200 ha.

Summary of Key Habitat Needs for the Upland Sandpiper in Tallgrass Habitats

Upland sandpipers prefer large blocks of grassland habitat (at least 30 ha, and preferably larger), with a predominance of native grass vegetation. Vegetation should have a diversity of heights, with some low (10–20 cm) areas for feeding and loafing and some taller areas (20–30 cm) for nesting. Cover >60 cm is avoided.

Northern Harrier (Circus cyaneus)

Range

The northern harrier is widely distributed across North America, and breeds in open wetlands and uplands across much of the United States except in the southeast (MacWhirter and Bildstein 1996). They are most numerous in the breeding season in the northern Great Plains from the Dakotas and Montana to southern Canada (Sauer et al. 1995). Harriers winter across much of the United States and as far south as Panama (MacWhirter and Bildstein 1996).

Population Status

The northern harrier is listed as a species of management concern by the FWS because of its dependence on vulnerable or restricted habitats (U.S. Fish and Wildlife Service 1995). Breeding Bird Survey data during the period 1966-1994 indicate that harrier populations have declined (2.1% per year, $P < 0.05$) in the Central BBS Region, and that these declines are concentrated in the Great Plains (Sauer et al. 1995). Harrier densities vary in response to local changes in the abundance of prey (MacWhirter and Bildstein 1996).

Phenology and Demographics

Northern harriers nesting in the Dakotas arrived during the first 2 weeks of March, and began egg-laying about the first week of May (Duebbert and Lokemoen 1977). Ninety percent of the nests in the Dakotas, Montana, and Manitoba were initiated in the period from May 3 to June 15 (Kantrud and Higgins 1992). The nestling period lasts an average of 6 weeks (MacWhirter and Bildstein 1996). Nest density in northwestern North Dakota averaged 0.34 nests/km^2 and correlated strongly with the relative abundance of voles (*Microtus* spp.) (Murphy 1993). MacWhirter and Bildstein (1996) reviewed 11 other studies and reported nest densities

ranging from <0.02 to 19.5/km^2. Harriers in eastern Minnesota nested as near as 183 m with little evidence of friction, although they were normally separated by at least 381 m (Breckenridge 1935). Nest success in northwestern North Dakota was 65%, with an average of 2.5 large young per occupied nest. Mammalian predation was the largest known cause of nest destruction in the north central United States and south central Canada (Kantrud and Higgins 1992).

Habitat Requirements

Northern harrier breeding habitats are open wetlands; wet, lightly grazed pastures; old fields; fresh and brackish marshes; and dry uplands including prairies, mesic grasslands, drained marshlands, croplands, cold desert shrub-steppe, and riparian woodland (MacWhirter and Bildstein 1996). Northern harriers are highly adaptive nesters (Hamerstrom and Kopeny 1981) and may select shrub stands within grasslands for nest sites (Toland 1986; Kantrud and Higgins 1992; Murphy 1993). Harriers nest in a wide variety of vegetative cover, including wet marsh meadows and dry grasslands (native and tame), mostly in dense, tall vegetation away from disturbance (MacWhirter and Bildstein 1996). Wet sites may be preferred because of less predation in such areas. Nests in upland sites in the Dakotas were in tall, dense cover that was not annually mowed, grazed, or burned, providing an essential component of accumulated residual vegetation for 2–5 years (Duebbert and Lokemoen 1977). Most nests (52%) were in cover >60 cm tall, many (42%) in cover 30–60 cm, and a few (7%) in cover 15–30 cm. Nest sites were in very dense cover and concealed from vision at a 1 m distance. Nest sites in the Dakotas, Montana, and Manitoba usually had 100% visual obstruction >3.5 dm and effective vegetation height >5.5 dm (Kantrud and Higgins 1992). Harrier night roosts in central Wisconsin were in open grass-forb areas, and day roosts were in similar areas or in brushy areas (Hamerstrom and Wilde 1973).

The northern harrier is an opportunistic predator whose summer diet consists primarily of rodents, birds, reptiles, and frogs (MacWhirter and Bildstein 1996). Harrier densities and productivity are strongly influenced by prey availability in the spring. Harriers in Arkansas avoided hunting in rodent-rich patches of tall corn and also avoided patches of bare ground, which had few rodents (Preston 1990). In Idaho shrub-steppe habitat, harriers discontinued hunting in alfalfa fields when heights exceeded 46 cm (Martin 1987).

Area and Landscape Considerations

Several studies indicate that northern harriers are sensitive to the size of available habitat. In Illinois grasslands ranging in size from 0.5 to 650 ha, the minimum area of encounter for northern harriers was >30 ha (Herkert 1991). Harriers in North Dakota CRP fields were uncommon in blocks of contiguous grasslands <100 ha [D. H. Johnson, unpublished data, cited by Johnson et al. (1998)].

Summary of Key Habitat Needs for the Northern Harrier in Tallgrass Habitats

Northern harriers require large areas, at least 10–30 ha in size, and are uncommon in grasslands <100 ha. Preferred nesting habitat is tall and dense, not annually burned, mowed, or grazed, and away from disturbance. Vegetation height at nest sites is often >60 cm and often with 100% visual obstruction >35 cm. Foraging habitat should provide an abundance of prey, with vegetation of low to intermediate heights (<46 cm).

Grasshopper Sparrow (Ammodramus savannarum)

Range

The grasshopper sparrow breeds across much of the United States, but is often locally distributed and uncommon to rare throughout parts of its range (Vickery 1996). This sparrow occupies drier, sparser sites in lush tallgrass prairies. Grasshopper sparrows reach their highest levels of abundance on the Great Plains from North Dakota south to Kansas (Sauer et al. 1995). The winter range extends from the southeastern United States to Central America (Vickery 1996).

Population Status

The grasshopper sparrow is listed as a species of management concern by the FWS because of its dependence on vulnerable or restricted habitats (U.S. Fish and Wildlife Service 1995). Berkey et al. (1993) also list the grasshopper sparrow as a species of special concern because of the high rate of population decline in recent years. The annual rate of decline from 1966–1994 was 4.9% (P <0.01) in North Dakota and 3.7% across the entire United States (Sauer et al. 1995). Vickery (1996) noted population declines of this sparrow are due to

habitat loss, conversion of pasture to intensive row crops, and lack of fire in grasslands.

Phenology and Demographics

Grasshopper sparrows arrive in Minnesota mainly from early to mid-May and depart gradually from August through September (Janssen 1987). Smith (1963) noted that two broods are produced, one in late May and a second in late June or early July. In a 3-year study in Maine, however, no evidence of successful second broods was found (Vickery et al. 1992). Grasshopper sparrow densities in North Dakota ranged from a mean of 10 territorial males per 40 ha in grazed native prairie, to 9.6 per 40 ha in idle native grassland, to 4.3 per 40 ha in alfalfa-wheatgrass grasslands (Renken and Dinsmore 1987). Nest success varies considerably throughout the range of the grasshopper sparrow, and is often low due to high rates of nest predation (Vickery 1996). Nest parasitism by brown-headed cowbirds (*Molothrus ater*) is generally lower for grasshopper sparrows than other grassland birds, but parasitism rates are variable across the range.

Habitat Requirements

The optimum range of vegetation heights for grasshopper sparrows in Missouri grasslands was 20–30 cm, and vegetation >40 cm was avoided (Kahl et al. 1985). Skinner (1975) reported that these sparrows were most dense at grass heights of 10.2–30.4 cm. Herkert (1994b) found a negative correlation between grasshopper sparrow occurrence and grass height in Illinois, and in a study of Iowa CRP fields, Frawley and Best (1991) noted that sparrow densities declined when alfalfa was ≥30 cm tall. Densities were also negatively correlated with vertical cover (Robel pole readings) in another Iowa CRP study (Patterson and Best 1996).

Grasshopper sparrows were significantly more common in dry Missouri prairies than either wet ($P < 0.001$) or mesic ($P < 0.05$) prairies (Swengel 1996). In addition, they were more common in undegraded (less woody and weedy invasion and higher native flora diversity) than degraded prairies ($P = 0.017$). Grasshopper sparrows used native grasses in Iowa prairies, but were not found in stands of Kentucky bluegrass (*Poa pratensis*) (Kendeigh 1941). On CRP fields in the northern Great Plains, grasshopper sparrow densities were negatively correlated with the percent cover of legumes ($P < 0.001$) (Johnson and Schwartz 1993).

Grasshopper sparrows forage exclusively on the ground and select moderately open grassland with patchy bare ground (Vickery 1996). They were the most common breeding bird in a prairie restoration of an old cornfield in eastern South Dakota in the second season after planting when patches of vegetation alternated with patches of bare ground (Blankespoor 1980). Densities were much reduced the next year probably because the luxuriant vegetation precluded large patches of bare ground. In West Virginia, grasshopper sparrows preferred bunch grasses over sod-forming grasses which precluded effective foraging (Whitmore 1981). Grasshopper sparrow territories in this study had more bare ground (21.9%), lower basal area cover of grasses (25.7%), lower shrub cover (0.7%), and lower litter depth (2.4 cm) than non-territories (respectively, 3.6%, 84.1%, 31.1%, and 6.6 cm).

Areas with extensive shrub cover are generally avoided by grasshopper sparrows (Vickery 1996). In Missouri, these sparrows preferred areas with no woody invasion >1 m tall, but did use a few woody stems <1 m tall or tall forbs for song perches (Kahl et al. 1985). In North Dakota mixed prairies, there was no significant difference in grasshopper sparrow density on shrubby versus shrubless transects, but shrub heights were much less than 1 m (Arnold and Higgins 1986).

In a study of CRP fields in southeastern Nebraska, Delisle and Savidge (1997) found that sparrow abundance (y) was positively related to percent litter cover (LC) and the percent of the canopy that was grass (GC) and negatively related to vertical density (VD) (dm) and litter depth (LD) (cm) ($R^2 = 0.72$):

$$\sqrt{y} = -3.7 + 0.58(LC) - 0.53(VD) - 1.76(LD) + 0.14(GC)$$

Nest predation rates were lower in vegetation that was recently burned (≤3 years) in Minnesota tallgrass prairies (Johnson and Temple 1990). The relative abundance of grasshopper sparrows (in June and July) was significantly higher on unburned northern mixed prairies in South Dakota than in burned (May 3) prairies (Huber and Steuter 1984). Grasshopper sparrows were approximately half as dense in heavily grazed areas than in lightly grazed areas (Kantrud 1981). Vickery (1996) notes that light to moderate grazing is generally beneficial to grasshopper sparrows. Early season mowing is responsible for a great deal of nest failure in grassland birds (Vickery 1996). Grasshopper sparrow populations tripled in 6 years as a result of deferring mowing until August at an Air Reserve Base in Massachusetts [Melvin (1994), cited by Vickery (1996)]. Sparrow detection rates were 1.59 times higher in hay prairies (hayed in late June to late July, hayed about every 2 years) than fire prairies (March or April burns, burned an average of every 2.5 years) in Missouri (Swengel 1996). The effects of various management practices on the grasshopper sparrow were summarized by Johnson et al. (1998).

Area and Landscape Considerations

The abundance of grasshopper sparrows is positively associated with habitat area (Herkert et al. 1993; Bollinger 1995; Helzer 1996). In Illinois grasslands ranging from 0.5 to 650 ha in size, the minimum area of encounter was 10–30 ha (Herkert 1991). The area needed for grasshopper sparrows to reach 50% incidence was reported as 8 ha in wet meadow fragments in Nebraska (Helzer 1996), 30 ha in Illinois (Herkert 1994b), and 100 ha in grasslands in Maine (Vickery et al. 1994). Nest predation rates were lower in large (130–486 ha) tallgrass fragments in Minnesota than in small (16–32 ha) fragments (Johnson and Temple 1990).

Grasshopper sparrows prefer areas that are distant from woody and other edges. Sparrow abundance was negatively associated with the perimeter-area ratio in Nebraska (Helzer 1996). Grasshopper sparrows were more abundant >75 m (year 1) and >100 m (year 2) from a woodland edge, and more abundant >50 m from a cornfield edge. There were no differences in abundance in relation to proximity to a 2-track gravel road edge. None of 10 nests found in CRP fields in Nebraska were <50 m from an edge (road, woody, or crop) (Delisle and Savidge 1996). Nest predation and brood parasitism in Minnesota tallgrass were lower in areas >45 m from a woody edge (Johnson and Temple 1990). Grasshopper sparrow abundance on a 20-ha Iowa prairie declined from 16 individuals in 1940, when shrubs and trees covered 5.4% of the area, to 0 individuals in 1988 when shrub and tree cover had increased to 50.3% (Bernstein et al. 1990).

Summary of Key Habitat Needs for the Grasshopper Sparrow in Tallgrass Habitats

Grasshopper sparrows require moderately large blocks of grassland habitat, preferably >30 ha in size. Vegetation heights should range from 10–30 cm, and areas above 40 cm are avoided. Dry prairies with a high percentage of grass cover and in undegraded condition are preferred. Grasshopper sparrows prefer open grassland habitats with high amounts of bare ground, abundant litter cover of low depth, low amounts of shrub cover, and no woody vegetation >1 m tall.

Bobolink (Dolichonyx oryzivorus)

Range

The bobolink breeds across the northern half of the United States and winters in the pampas region of South America (Martin and Gavin 1995). Bobolinks reach their highest abundance in eastern North Dakota, northwestern Minnesota, and southeastern Canada (Sauer et al. 1995).

Population Status

Data from the BBS indicate that bobolinks have undergone widespread population declines across North American (4.4% per year from 1980–1994) (Sauer et al. 1995). No state or BBS region had a significant increasing trend during this period. Agricultural hay cropping may be contributing to this decline because of high levels of mowing-induced mortality in bobolink populations (Bollinger et al. 1990). The bobolink is on the Audubon Society's Watchlist because of threats such as: (1) habitat loss due to changing land-use practices, especially the decline of meadows and prairies, and the cutting of hayfields during peak nesting periods; (2) predation on eggs and nest exposure to flooding; and (3) nest parasitism by brown-headed cowbirds (Muehter 1998).

Phenology and Demographics

Male bobolinks generally arrive on the breeding grounds in early May and nest initiation begins in mid- to late-May (Martin and Gavin 1995). Average densities (males/km^2) in tallgrass prairies were 26 ± 19 and 91 ± 70 in New York hayfields. Fledgling success is slightly greater than 50%, with a mean of 2.29 young per clutch. The intensity of nest parasitism by brown-headed cowbirds varies geographically. In western Minnesota, nest success was higher for nests located >45 m from a forest edge (Johnson and Temple 1986). Nest predation and weather are likely the most significant causes of mortality (Martin and Gavin 1995).

Habitat Requirements

Bobolinks nest on the ground, often placing the nest at the base of large forbs in grass-dominated meadows (Martin and Gavin 1995). Bobolink densities were positively correlated with percent grass cover in two CRP studies (Johnson and Schwartz 1993; Patterson and Best 1996). In the Iowa study, densities were also positively correlated with percent litter cover and negatively correlated with percent forb cover and horizontal patchiness (Patterson and Best 1996). In Missouri grasslands, Skinner (1975) noted that bobolinks were most dense when grass heights were 10.2–30.4 cm. The relative abundance of bobolinks in Nebraska CRP fields was negatively related to vertical density and positively related to percent litter cover (Delisle and Savidge 1997). Bobolink occurrence in Illinois grasslands was positively

associated with the mean number of live forb contacts, mean vegetation height, and mean grass height, and negatively associated with an index of heterogeneity (Herkert 1994b). Grass heights on bobolink territories in Oregon ranged from an average of 16 cm in early to mid-May to 25 cm on May 20 up to 51 cm by June 14 (Wittenberger 1980). Bobolinks in Wisconsin preferred treeless grassland habitats with dense, lush vegetation (Sample 1989). Living vegetation surrounding 10 bobolink nests in Ontario ranged in height from 33 to 41 cm (Joyner 1978).

Kantrud (1981) related bird densities to land use practices in native grasslands of North Dakota. Bobolink density was highest [145 pairs/(minute x 10^3)] in mowed native grasslands during the second year after they were hayed and contained tall, dense grasses. In grazed grasslands, bobolinks were absent from heavily grazed areas and achieved low densities [7 pairs/(minute x 10^3)] in moderately grazed areas and intermediate densities [39 pairs/(minute x 10^3)] in lightly grazed areas.

Bobolink abundance in New York hayfields increased with increasing age of the field (Bollinger 1995). Vegetation shifted from dense, homogeneous communities dominated by legumes to more sparse, patchy, grass-dominated communities as fields aged. Bollinger (1995) noted that because of higher productivity in the eastern United States, the least productive fields probably approximated the more productive prairie habitats of the Midwest in terms of vegetation height and density.

Area and Landscape Considerations

The density of bobolinks is positively associated with habitat area (Bollinger and Gavin 1989; Helzer 1996). In Illinois grasslands ranging in size from 0.5 to 650 ha, the minimum area of encounter for bobolinks was 10–30 ha (Herkert 1991). Bobolinks were most abundant on plots that were part of larger (>50 ha) CRP tracts in Iowa (Patterson and Best 1996). In Nebraska, bobolinks reached 50% incidence in patches of 46 ha, and their abundance was negatively correlated to the perimeter-area ratio, indicating a preference for larger habitat blocks with less edge (Helzer 1996). Bobolinks in Illinois grasslands reached 50% incidence at 50 ha (Herkert 1994b). Nest predation rates in Minnesota tallgrass habitats were lower in large (>130 ha) fragments (Johnson and Temple 1990). Nest predation and brood parasitism rates were lower in areas far (>45 m) from a woody edge. Bobolink abundance was higher in areas >75 m (year 1) and >100 m (year 2) from a woodland edge (Helzer 1996). Bobolink abundance on a 20-ha Iowa prairie declined from 16 individuals in 1940, when shrubs and trees covered 5.4% of the area, to 0 in 1988 when shrub and tree cover had increased to 50.3% (Bernstein et al. 1990).

Summary of Key Habitat Needs for the Bobolink in Tallgrass Habitats

Bobolinks require large habitat blocks, at least 10–30 ha in size, and preferably >50 ha. Improved conditions are provided when the amount of habitat edge is minimized and distance to woody edge exceeds 45 m. Bobolinks prefer fairly tall, dense habitats with a high percent of grass cover with some forbs mixed in, with vegetation heights of at least 10.2–30.4 cm, and abundant litter cover.

Rare Butterflies

Habitat for regal fritillaries includes tallgrass prairie and other open sites such as damp meadows, marshes, and wet fields (Opler et al. 1995). The primary habitat for the regal fritillary is tallgrass prairie, and violets (*Viola* spp.) provide the primary food for larvae (Swengel 1997). The regal fritillary ranges from Montana and North Dakota, south to Colorado, Nebraska, and Oklahoma, and is rare or absent from its former range east of the Appalachians (Opler et al. 1995). In the Dakotas and Minnesota, this fritillary was more abundant in drier prairies, prairies >65 ha in size, and prairies that were hayed rather than burned (Swengel 1997). Floristic quality is important in the distribution of the regal fritillary, although the above factors may limit its abundance more than prairie quality in some areas. Adult foods of the regal fritillary include nectar from milkweeds (*Asceplias spp.*), thistles (*Cirsium spp.*), and blazing star (*Liatris spp.*) (Royer 1997).

Habitat for the Dakota skipper consists of mesic tallgrass to midgrass native prairies containing death camas (*Zygadenus elegans*) (Royer 1997). Larval foods are grasses, especially little bluestem (*Schizachyrium scoparium*). Dakota skippers range from southern Manitoba and western North Dakota to western Minnesota, south to northwest Iowa (Opler et al. 1995).

Powesheik skipperlings occur almost exclusively in the Dakotas and Minnesota, with one site each in Iowa and Michigan (Opler et al. 1995). Their habitat is virgin fresh tallgrass meadows, and the larval food is an unknown sedge or grass, possibly spikerush (*Eleocharis spp.*) (Royer 1997). Adult foods include nectar from a variety of flowers (Opler et al. 1995). The Dakota and powesheik skippers require relatively undisturbed areas (Opler 1981).

In North Dakota, the arogos skipper occurs in mesic, undisturbed tall- to mid-grass native bluestem prairies and big bluestem is a primary larval food (Royer 1997). These skippers occur in isolated colonies primarily in the Great Plains from North Dakota to Texas, but also in scattered locations in states along the Atlantic and Gulf coasts (Opler et al. 1995). Adult foods include nectar from a variety of flowers.

Tallgrass Floral Diversity

Knopf and Samson (1997) describe drought, fire, and grazing as the ecological drivers of Great Plains grassland ecosystems. Presettlement prairies were dynamic systems containing a variety of successional stages created by disturbances and sequential development of these stages (Kline 1997). Major impacts following European settlement included the introduction of exotic herbaceous and woody plants, the reduction of native seed sources due to the tremendous increase in the amount of plowed land, and the cessation of fire. Historically, fire restricted woody growth to riparian and other protected areas (Steinauer and Collins 1996). In addition, heavy grazing by cattle resulted in degraded prairies with lower native diversity and an increased abundance of exotic plants (Weaver 1954). Much of the tallgrass prairie ecosystem was lost prior to having received extensive ecological study, and many basic ecological questions remain (Steinauer and Collins 1996).

Shenk and Lenz (1998) provide descriptions of 12 prairie types that currently exist in eastern North Dakota. Wet types include northern reedgrass wet meadow and wet prairie. Mesic and dry-mesic types include wet-mesic tallgrass prairie, wet-mesic sand tallgrass prairie, mesic tallgrass prairie, mesic sand tallgrass prairie, central mesic tallgrass prairie, dry-mesic tallgrass prairie, dry-mesic sand tallgrass prairie, and mesic mixed grass prairie. Dry prairie types include sand mixed grass prairie and sand prairie. Native prairie remnants are largely confined to areas where soil properties or topography have precluded conversion to agriculture. This has resulted in the almost total loss of prairie types historically found on level, rich soils, such as mesic tallgrass prairie.

Ladd (1997) lists 477 species of vascular plants that occur in tallgrass prairies in North Dakota. Of these, 64 are listed as threatened or endangered by the North Dakota Game and Fish Department. Over 70% of the flora within Midwestern tallgrass prairies consists of herbaceous perennials, and perennial forbs account for slightly more than 50% of the vascular plant species. Graminoids are prevalent throughout prairie systems, but account for somewhat less than a quarter of total species richness. Of the nearly 1,000 species of vascular plants that occur in Midwestern tallgrass prairies, 55% are designated as species of concern in one or more states or provinces.

Establishing Habitat Objectives

The purpose of habitat objectives is to provide clear, unambiguous statements describing the desired conditions of habitat features required for the resources of concern. Development of explicit, measurable, scientifically sound habitat objectives is a critical aspect of the CCP process on refuges. Habitat objectives should be derived from a comprehensive assessment of existing knowledge, and the logic for each objective should be supported by the scientific information summarized for the resources. Well-worded habitat objectives also provide the foundation for habitat monitoring efforts. Habitat objectives should describe the "who, what, where, when, and why" as recommended in the U.S. Fish and Wildlife Service Handbook (U.S. Fish and Wildlife Service 1996).

A habitat model can be a useful tool in guiding management efforts on refuges (Johnson et al. 1994; Schroeder et al. 1998). Models can clearly express the logic and assumptions used to develop specific objectives. As noted by Thomas (1986:xxii) "Models are a formalized way of guiding adaptive management of our natural resources." Because many migratory birds in northern prairies exhibit dynamic population responses to precipitation, temperature, and land management such as grazing or burning, specific population objectives are not feasible and the desired approach should be "to provide the habitat base that – when other environmental conditions are right – will support desired and sustainable populations" (Johnson 1995:62). A habitat model documents what is required to provide such a habitat base for long-term support of resources of concern.

Models can range from simple words to complex mathematical equations (Verner et al. 1986). A useful habitat model should have a clearly defined and testable output (Schroeder and Haire 1993). This allows the model to be understood and allows for monitoring and evaluation in an objective manner.

Our approach to establishing habitat objectives is to identify key habitat and landscape variables that, if managed properly, will produce a tallgrass community that improves productivity for the four key bird species, increases the abundance and distribution of the rare butterflies, and improves the diversity of the tallgrass flora. As noted earlier, we believe that management for these resources will contribute substantially toward meeting the goal of restoring and maintaining native

biodiversity. Management for these resources should have a positive effect on the issues of concern in tallgrass prairies that were listed earlier:

- small size of contiguous patches
- lack of natural processes
- increase in the amount of woody vegetation, especially trees
- loss of diversity in plant community
- invasion by exotic plants
- rare or declining species, including grassland birds and butterflies

Specific, quantitative habitat objectives can be developed for each of the key habitat variables to guide management actions and provide a focus for monitoring. An important factor to consider in establishing specific levels for each habitat objective is the historical, or presettlement, conditions of a refuge. These conditions may provide a desirable long-term target. Meffe and Carroll (1994:413) note that:

> "The process of restoration actually involves setting the system on a new development trajectory toward its particular "target," its former state. How far along that trajectory the system goes depends on a number of things, including the level of knowledge of the previous state; how perturbed the system is; availability of biota for restoration; genetic variation of the biota; the level of alteration of hydrology, soil, and geomorphology; cost and available funding; and political will. Many times the product will not be an exact replica of the former system, but rather represents a major change in trajectory toward the target."

Key Variables and Habitat Objectives

Effective Area of Tallgrass Habitat

Effective area is defined as the area of contiguous grassland habitat that is >50 m from woody vegetation (trees or tall shrubs, e.g., woody vegetation >1 m tall). This area should include all grasslands, regardless of their floristic quality (which will be rated separately). The concept of "effective area" is derived from studies indicating that the productivity of certain grassland bird species is positively associated with grassland size and distance from woody edges. Kline (1997) noted that the effective size of a prairie habitat is larger if surrounding areas are not wooded.

Upland sandpiper, grasshopper sparrow, and bobolink abundances are positively associated with grassland area. Northern harriers are uncommon in grasslands less than 100 ha in size. Nest predation rates are lower for grasshopper sparrows and bobolinks in larger grasslands. Abundance of grasshopper sparrows and bobolinks is negatively correlated with the perimeter-area ratio of grassland patches. Grasshopper sparrows and bobolinks are more abundant in areas far from woody edges. Minimum grassland size requirements are 30 ha for the upland sandpiper and northern harrier and 10 ha for the grasshopper sparrow and bobolink. Areas smaller than these are very unlikely to be occupied. Large grassland areas provide the highest levels of species richness of wildlife and flora, and are less vulnerable to invasion by exotic plants. Thus, it can be seen that the larger the area of a grassland patch and the more of the area that is far from woody edges, the better the habitat is in terms of potential productivity and survival for the resources of concern.

Establishing a habitat objective for effective area. In establishing an objective for effective area, it would be helpful to know the historical extent of grasslands and woody vegetation. Removal of trees along a riparian corridor to increase the effective area of grasslands may not be desirable because such trees may be naturally occurring and historically present. Planted shelterbelts or areas of woody encroachment into historically open prairies, however, are likely candidates for management activities. In addition, conversion of cropland to grassland can increase the effective area. An example of an objective for effective area is:

> The refuge (who) will eliminate 5 ha of trees (what) adjacent to or within grassland patches (where) per year, for a period of five years (when), and a total removal of 25 ha, to increase the effective area of those patches and thereby improve conditions for declining grassland birds, butterflies, and native flora (why).

Measurement suggestions. Effective area may be assessed through the use of a geographic information system (GIS). This would require establishing a 50-m buffer around all woody vegetation and computing effective grassland area by reducing the size of the grasslands by the amount of area in these buffers. This could also be done on hard copy maps with a scale, planimeter, or dot grid.

Floristic Quality of Tallgrass Habitat

The quality of the flora of tallgrass prairies is an important resource of concern. Upland sandpipers nested most often in native grasslands, and within native grasslands, may prefer sites with a high percent of climax species. Grasshopper sparrows were more common in undegraded prairies, with less woody and weedy invasion and a higher native flora diversity. Floristic quality is also important for the conservation of rare butterflies.

A system known as the floristic quality assessment (FQA) has been developed to measure the quality of tallgrass communities in the Midwest (Masters 1997). This assessment is based on the concept of plant species conservatism. Conservatism reflects the degree that a prairie has the structure, composition, and processes of intact presettlement conditions. Native prairie plants exhibit a range of conservatism, wherein some species are ubiquitous and commonly found in degraded conditions, and others are more restricted and found only in high-quality areas. A rating system with scores ranging from 0 to 10 has been developed, with a 0 score indicating a native species most commonly found in recently disturbed areas, and 10 indicating a native species restricted to a high-quality prairie. A site with a large proportion of conservative plants will have a higher mean rating (C value) than a site with a lower proportion of such plants.

The species richness of sites can be considered and incorporated into the rating system. The resultant floristic quality index (FQI) is calculated by multiplying the mean C by the square root of the total number (n) of native species recorded (Masters 1997):

$$FQI = C\sqrt{n}$$

An FQI (per 0.25 m^2) is typically ≥ 20 for a very high quality prairie, between 5 and 10 for a degraded remnant, and between 2 and 5 for a low-quality restoration (Packard and Ross 1997). Conservatism scores for native tallgrass plants have been developed for Illinois and Missouri (Taft et al. 1996; Ladd 1997), but not for the Dakotas or Minnesota. Because of the climatic and geographic differences between the areas, the C scores from Illinois and Missouri cannot be extrapolated to the Dakotas and Minnesota (Doug Ladd, The Nature Conservancy, Missouri, personal communication). Until such time as C scores are developed, we recommend that floristic quality be assessed using the following approach.

Shenk and Lenz (1998) developed a system to rank tallgrass prairies in a 12-county area in North Dakota just north of Tewaukon NWR. The purpose of the ranking system was to provide a simple means of comparing ecological quality and importance of prairie areas. One criteria in the ranking system was percent native plant cover. Tallgrass prairies can be rated from 0 to 100%, with 0% being a system with no native plant cover and 100% being a system that is 100% native plant cover. A second criteria was native plant species richness (number of native plant species). For the 12-county area, sites with 0 native species represent the worst case and sites with 51 or more native species represent the best case. Native richness was assessed during a single 2–3 hour site visit, and is probably a conservative estimate of total native plant species richness because of the limited time and seasonality of the visit.

Native grasses and forbs typically found in wet, mesic, and dry tallgrass prairies in Minnesota and North Dakota are presented in the Appendix.

Establishing a habitat objective for floral quality. An example of an objective for floral quality is:

> The refuge (who) will increase native plant cover from 50 to 100% (what), and increase native species richness from 30 to 51 (what) in a specified area (where) over the next 10 years (when) for the purpose of improving tallgrass prairie floral quality (why).

Measurement suggestions. Native plant cover can be assessed by either measuring cover along a transect or within a plot. Native species richness in the system developed by Shenk and Lenz (1998) was assessed by counting species observed during a 2–3 hour one-time site visit.

Habitat Mosaic (Vegetation Heights)

A mix of vegetation heights is necessary in tallgrass prairies to support a wide array of species. Upland sandpipers appear to prefer cover of 15 to 35 cm in height for nesting, slightly lower heights (<10 to 30 cm) for feeding, and avoid tall (>60 cm), dense areas. Northern harriers prefer to nest in tall, dense vegetation with heights >60 cm, and forage in areas with shorter vegetation (avoid areas >46 cm). Grasshopper sparrows prefer nesting cover approximately 20–30 cm in height and avoid areas with vegetation >40 cm. Bobolinks appear to prefer nesting vegetation in the range of 20 to 40 cm in height. Management for a habitat mosaic should attempt to mimic the natural dynamics and variation in tallgrass prairies. Internal or horizontal variation and variation over time are also important, and management should not attempt to create and maintain very large patches at uniform heights at the same locations over long periods.

Establishing a habitat objective for habitat mosaic (vegetation heights). Given the different needs of the four bird species, a specific objective for the habitat mosaic (vegetation heights) variable is more difficult to establish.

Management emphasizing any single height across the entire area will not provide for the varying needs of these species. A reasonable approach might be to assess existing conditions and determine the percent of area in each of three general height categories (10–30, 30–50, and >50 cm). Based on these existing percentages and the species' habitat needs, an objective could be established to increase or decrease the amount of area in a particular height class for the benefit of one or more of the species. For example, assume the existing situation consisted of tall (>50 cm), dense grasslands in all areas. This condition could be improved by managing some areas to achieve heights of 10–30 cm and other areas to achieve heights of 30–50 cm. The exact desired proportions and amount of area in each height category are somewhat arbitrary choices, but the desired mix should be explicitly stated as the habitat objective, along with the logic used in its development.

Measurement suggestions. Vegetation heights should be measured in late May to early June, during the nesting period for these birds. Many of the studies that reported vegetation height preferences for the four bird species did not explicitly describe the method used to determine height. Based on the studies that did provide this information, we recommend measuring the mean height of the top of the leaf canopy of the grasses. The habitat mosaic effect can be measured by mapping the amount of area in each of the three height classes and determining the percentage in each category.

Amount of Shrub Cover

Specific data on preferences for various levels of shrub cover was not found for all four bird species. Grasshopper sparrows clearly prefer areas with few or no shrubs, and it appears the same is true for upland sandpipers and bobolinks. Northern harriers may nest or roost in areas with some shrub cover. Shrub invasion is a serious concern on some areas of tallgrass prairie, and to benefit most open prairie species, shrub cover should be very low. An allowance for some shrub growth in areas of historical occurrence, or in patterns approximating natural dynamics is appropriate (Solecki 1997). Such information should be sought, but may be difficult to obtain.

Establishing a habitat objective for shrub cover. The presence of shrub cover is not an absolute requirement for any of the resources of concern, and shrub cover has a negative effect on several species. The specific amount and location of any shrub cover that is desired should be explicitly stated as the habitat objective. Where shrub cover was historically absent, a reasonable objective might be to eliminate shrub cover in tallgrass habitats. Where shrub cover was historically present, a reasonable objective would be to approximate the historical distribution and abundance of such cover, mimicking natural dynamics over time.

Measurement suggestions. The canopy cover of shrubs can be measured in plots or along transects. It may be possible to assess shrub cover from remotely sensed data, if such data are at the appropriate level of detail. Shrubs are defined as woody vegetation <5 m in height.

Potential Habitat Management Strategies

Habitat management strategies must be selected and implemented to achieve the desired conditions for the habitat variables. The long-term goal should be to attain the specific habitat objective for each of the areas and habitat factors. We recommend focusing initial management efforts on maximizing effective area, particularly in areas with an abundance of tall woody vegetation. Reducing woody vegetation is usually an ongoing management effort, particularly in Minnesota and the eastern Dakotas. Removal or top-killing by cutting, brush-mowing, or burning can be initially measured, but follow-up measures are important to evaluate the effectiveness over time. The next level of management actions should be directed at providing the desired mosaic of vegetation heights and reducing any excess shrub cover. These management actions also require maintenance over time. Management to improve floral quality is best undertaken as an ongoing effort that will result in gradual improvements over a long period of time.

There are a wide variety of possible management strategies that can be used, and exact prescriptions for a specific site must be made by managers familiar with the site. Ryan (1990:103) provided several excellent points describing the difficulties in trying to prescribe site-specific management actions:

> "The current literature is valuable in describing approaches to prairie management but it cannot be used as prescriptions for on-site management actions."

> "Combinations of soils, topography, existing plant community, management history, climatic conditions, timing of treatments, etc. produce unique results spatially and even temporally at the same site. There is no substitute for

experienced managers and their creative experimentation with available tools."

Our approach is to suggest a few possible management actions related to each variable and provide references to additional information. We strongly recommend that managers study the available literature, contact other managers in their area that have dealt with similar issues, and use the principles of adaptive management.

Effective Area

The effective area of a grassland patch can be increased by converting croplands or other non-grassland types to grassland or by removing woody vegetation within or adjacent to grasslands. Guidelines for establishing tallgrasses are provided by Duebbert et al. (1981) and Packard and Mutel (1997). Recommendations for controlling woody vegetation are provided by Solecki (1997). Ongoing maintenance and evaluation are important in controlling woody vegetation.

Floristic Quality of Tallgrass Habitat

Improving the floristic quality of tallgrass prairies is difficult and time consuming. Problems often exist with invasive exotic vegetation [e.g., leafy spurge (*Euphorbia escula*), smooth bromegrass (*Bromus inermis*), Kentucky bluegrass] and lack of native broad-leafed forbs. Management practices to deal with these problems include burning, interseeding, and possibly herbicide application. Control measures can be harmful to nontarget species, and managers should seek to use the least damaging approach. Restoration of natural processes, such as fire, will often result in gradual improvements over a longer time period. More aggressive measures, however, may be needed against alien plants that spread rapidly. Solecki (1997) provides detailed advice on controlling invasive plants.

There has been a tremendous amount written and published about prescribed burning in prairie habitats. Appropriate timing and frequency of burns has been a subject of much discussion, and there is not a consensus on the best strategies to achieve particular objectives. A research review (Wright and Bailey 1980), annotated bibliography (Higgins et al. 1988), symposium publication (Collins and Wallace 1990), and tallgrass restoration handbook (Packard and Mutel 1997) provide a number of useful ideas and citations. Use of fire in butterfly habitats should be approached with care, because local populations can be extirpated if entire fragments are burned and no refugia exist (Opler et al. 1995).

The floristic quality of a site often can be dramatically improved by interseeding native seeds within existing vegetation, without plowing. Specific details on this approach are provided by Packard (1997).

Habitat Mosaic (Vegetation Heights)

Management practices that influence vegetation heights include burning, grazing, and mowing. The effects of any one of these practices, or various combinations, vary depending on site-specific conditions. Publications related to burning are provided above in the discussion of floristic quality. In addition, useful summaries of the effects of burning, grazing, and mowing are found in Ryan (1986), Herkert et al. (1993), and Johnson (1995). An important component of managing for a habitat mosaic is to rotate areas of different heights, and not to maintain any one area in the same height class over a long time period.

Amount of Shrub Cover

Shrub cover can be manipulated primarily through controlled burning, mowing, cutting, and herbicide applications. Specific recommendations for controlling woody vegetation are provided by Solecki (1997).

Monitoring, Evaluation, and Adaptive Management

Application of the appropriate habitat management strategies to meet the habitat objectives should result in changes in habitat conditions that will increase productivity of the four bird species (over time), increase the abundance and distribution of the rare butterflies, and improve floristic diversity. The first consideration in monitoring the effectiveness of an application is to ensure that the desired habitat conditions were indeed produced. This can best be accomplished by comparing results after management with either baseline conditions prior to management or with control areas during management. In some cases, changes will be obvious, such as removing trees to increase effective area. In other cases, such as increasing floral quality, changes may be more subtle and their detection will require a more rigorous sampling approach.

The issue of the desired level of reliability of monitoring data should be considered prior to implementing a monitoring plan. There is no a priori level of statistical rigor that is mandated, and considerations might include both practical and biological factors.

Monitoring of the population response of the bird species or butterflies may be desired following evaluation of habitat changes. The key issue here is to determine the effectiveness of the implemented habitat changes in improving productivity of the birds or abundance and distribution of the butterflies. Such studies should be conducted over a period of at least several years to account for annual variation. It should be recognized that population levels of the four bird species may be influenced by events unrelated to habitat conditions on the refuge (e.g., weather, winter range problems). In addition, species such as the northern harrier have a large home range and detecting any changes in population levels may not be feasible on relatively small areas.

The entire process of habitat management on a refuge should be conducted within the context of adaptive resource management. Acquisition of new site-specific data, changes in species abundance levels, or other changes or new data may indicate that management should be adapted to respond to the new considerations. The overall process should always be focused, but flexible. In this manner, progress toward achieving habitat objectives can be monitored and appropriate modifications incorporated over time.

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Appendix. List of typical grasses and forbs in Minnesota and North Dakota in dry (D), mesic (M), and wet (W) tallgrass prairie sites. This list was developed from publications by the Minnesota Natural Heritage Program (1993) and the North Dakota Natural Heritage Inventory Program (Shenk and Lenz 1998).

	Minnesota			North Dakota		
	D	M	W	D	M	W
Graminoid Species						
Andropogon gerardii (big bluestem)	x	x	x		x	
Andropogon hallii (sand bluestem)				x		
Bouteloua gracilis (blue grama)	x			x		
Bouteloua curtipendula (sideoats grama)	x	x		x	x	
Bouteloua hirsuta (hairy grama)	x			x		
Calamagrostis stricta (northern reedgrass)					x	x
Calamovilfa longifolia (prairie sandreed)	x			x		
Carex lanuginosa (wooly sedge)						x
Carex heliophila (sun sedge)	x	x		x		
Distichlis stricta (salt grass)			x			
Eleocharis compressa (spikerush)						x
Hierochloe odorata (sweet grass)			x			
Juncus balticus (Baltic rush)					x	x
Koelaria macrantha (June grass)	x	x		x		
Muhlenbergia cuspidata (prairie satin grass)	x	x				
Muhlenbergia asperifolia (scratch grass)			x			
Muhlenbergia richardsonis (mat muhly grass)			x			
Panicum virgatum (switchgrass)		x		x	x	x
Panicum leibergii (prairie panic grass)	x	x				
Pascopyron smithii (western wheatgrass)					x	
Schizachyrium scoparius (little bluestem)	x	x	x		x	x
Scirpus pungens (three-square)						x
Scirpus pallidus (pale bulrush)						x
Sorghastrum nutans (Indian grass)	x	x		x	x	
Spartina pectinata (prairie cordgrass)			x			x
Spartina gracilis (alkali cord-grass)			x			
Sporobolus heterolepis (prairie dropseed)	x	x			x	
Sporobolus cryptandrus (sand dropseed)				x		
Stipa viridula (green needlegrass)					x	
Stipa spartea (porcupine grass)	x	x		x	x	
Stipa comata (needle and thread)				x		
Broad-leaved Herbs						
Allium stellatum (pink wild onion)	x	x				
Amorpha canescens (leadplant)					x	
Anemone canadensis (Canada anemone)					x	
Anemone cylindrica (thimbleweed)	x	x		x		
Apocynum cannabinum (prairie dogbane)						x
Artemesia dracunculus (green sage)				x		
Artemisia frigida (fringed sage)	x			x		
Artemisia ludoviciana (pasture sage)	x	x		x		

Appendix. Continued.

	Minnesota			North Dakota		
	D	M	W	D	M	W
Asclepias speciosa (showy milkweed)		x			x	
Ascelpias viridiflora (green milkweed)					x	
Aster laevis (smooth blue aster)	x	x				
Aster novae-angliae (New England aster)			x			
Aster oblongifolius (aromatic aster)	x	x				
Aster sericeus (silky aster)	x	x				
Aster simplex (panicled aster)					x	
Astragalus crassicarpus (Indian pea)	x	x				
Calylophus serrulatus (toothed evening primrose)	x	x				
Castilleja sessiliflora (downy yellow painted cup)	x					
Cirsium flodmanii (Flodman's thistle)	x	x				
Comandra umbellata (false toadflax)	x	x				
Coreopsis palmata (prairie coreopsis)	x	x				
Dalea candida (white prairie clover)		x				x
Dalea purpurea (purple prairie clover)	x	x				
Delphinium virescens (prairie larkspur)	x	x				
Echinacea angustifolia (purple coneflower)	x	x		x	x	
Euthamia graminifolia (grass-leaved goldenrod)			x			
Gentiana andrewsii (closed gentian)			x			
Geum triflorum (prairie smoke)	x	x		x		
Glycyrrhiza lepidota (wild licorice)		x				
Helianthus maximilianii (maximilian sunflower)		x			x	x
Helianthus rigidus (stiff sunflower)	x	x		x	x	
Heliopsis helianthoides (false sunflower)		x				
Heterotheca villosa (golden aster)	x	x				
Heuchera richardsonii (alum root)	x	x		x	x	
Hypoxis hirsuta (yellow star grass)			x			
Liatris aspera (blazing star)	x	x			x	
Liatris cylindracea (cylindrical blazing star)	x					
Liatris ligulistylis (blazing star)		x	x			
Liatris punctata (dotted blazing star)	x	x		x	x	
Liatris pycnostachya (tall blazing star)			x		x	
Lillum philadelphicum (wild lily)		x			x	
Lithospermum canescens (hoary puccoon)	x	x			x	
Lithospermum incisum (narrow-leaved puccoon)	x			x		
Lycopus americanus (American bugleweed)						x
Lysimachia quadrifolia (whorled loosestrife)			x			x
Oxalis violacea (violet wood sorrel)		x				
Pedicularis canadensis (lousewort)	x	x				

Appendix. Concluded.

	Minnesota			North Dakota		
	D	M	W	D	M	W
Phlox pilosa (sand prairie phlox)		x				
Plantago eriopoda (alkali plantain)			x			
Polygonum amphibium (water smartweed)						x
Potentilla arguta (prairie cinquefoil)	x	x				
Prenanthes racemosa (glaucous white lettuce)		x				
Psoralea argophylla (silver-leaf scurf pea)		x				
Psoralea esculenta (breadroot scurf pea)	x	x				
Pulsatilla nuttalliana (pasque flower)	x	x				
Pycnanthemum virginianum (common mountain mint)			x			
Rudbeckia hirta (black-eyed susan)					x	
Senecio plattensis (prairie ragwort)	x	x				
Sisyrinchium campestre (prairie blue-eyed grass)	x	x				
Solidago missouriensis (Missouri goldenrod)	x	x		x		
Solidago nemoralis (old-field goldenrod)	x	x	x			
Solidago ptarmicoides (stiff aster)	x	x				
Solidago riddellii (Riddell's goldenrod)			x			
Solidago rigida (stiff goldenrod)	x	x			x	
Stachys palustris (hedge nettle)						x
Thalictrum dasycarpum (purple meadow rue)		x	x			
Tradescantia occidentalis(prairie spiderwort)	x					
Tradescantia bracteata (spiderwort)				x		
Viola pedatifida (prairie violet)	x	x				
Zigadenus elegans (white camas)		x			x	
Zizia aptera (meadow parsnip)		x	x			x
Zizia aurea (golden alexanders)			x			

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13. ABSTRACT (Maximum 200 words)

National Wildlife Refuges are required to manage habitat in accord with an approved Comprehensive Conservation Plan containing specific, measurable habitat objectives. Tallgrass prairie habitat is of critical concern at the Tewaukon National Wildlife Refuge. Habitat management directed at improving conditions for declining bird species, rare butterflies, and a diversity of tallgrass flora is assumed to contribute substantially toward the broad goal of maintaining native biodiversity in tallgrass prairies. Such management should consider the size of tallgrass patches, the amount of woody vegetation, providing a mosaic of vegetation heights, and improving overall floristic quality. Selection of appropriate management strategies followed by monitoring and evaluation of habitat conditions will allow for adaptive management and appropriate modifications over time.

14. SUBJECT TERMS (Keywords)

Habitat, management, North Dakota, objectives, refuge, tallgrass, wildlife

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